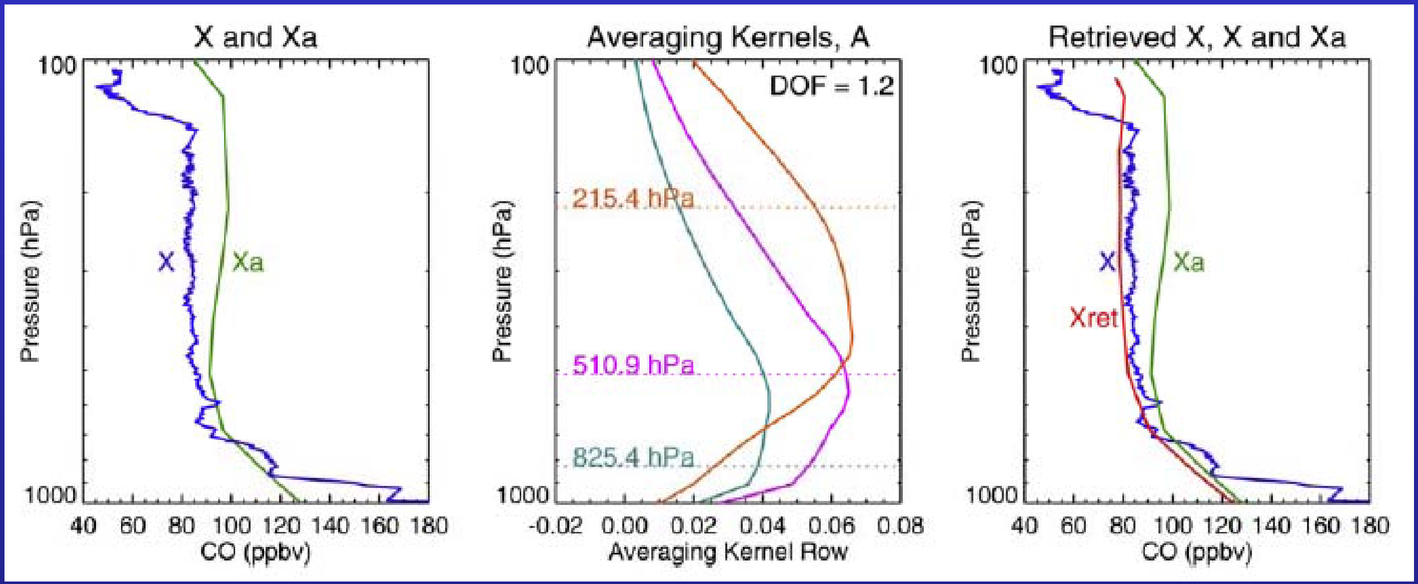
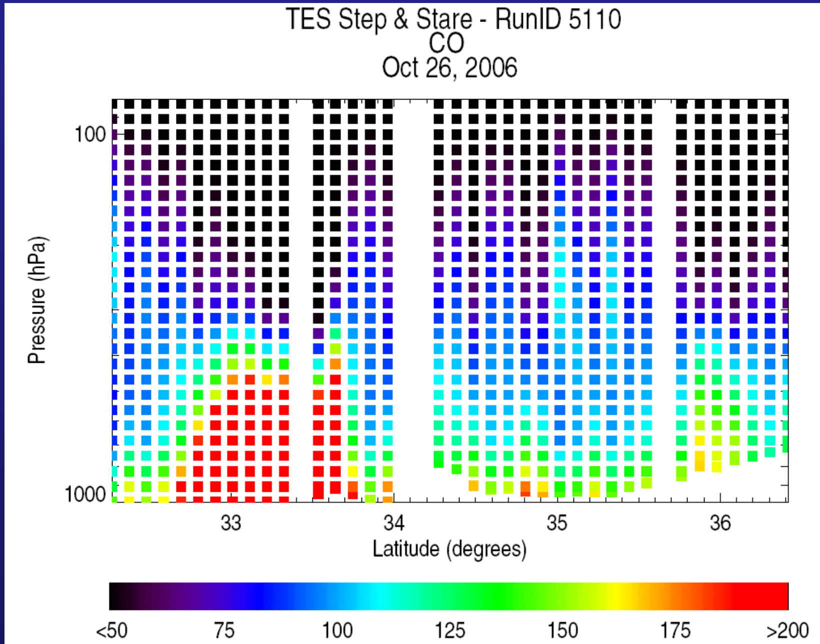
Challenges

Satellite instruments have limited sensitivity to O_3 and CO in the boundary layer



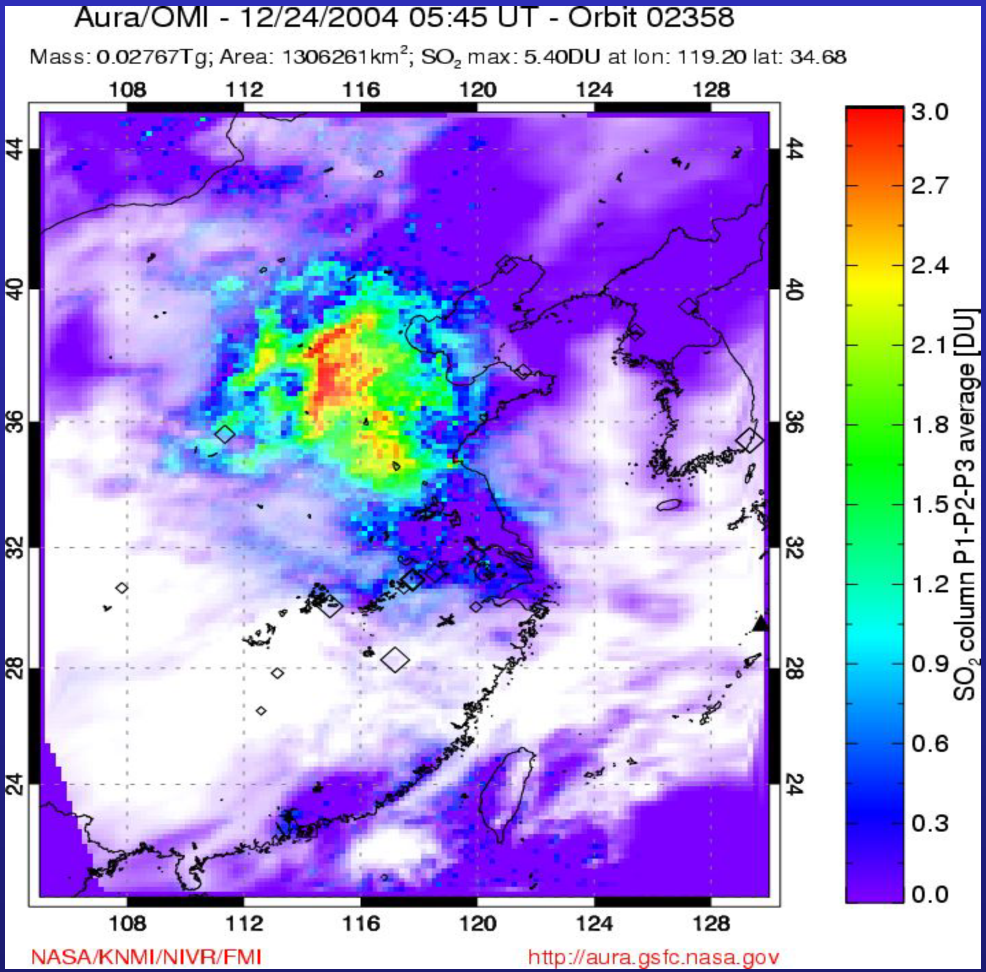
Luo et al. [2007]



Osterman, Richards, Worden et al. [2007]

Satellite Retrievals of Boundary Layer SO_2

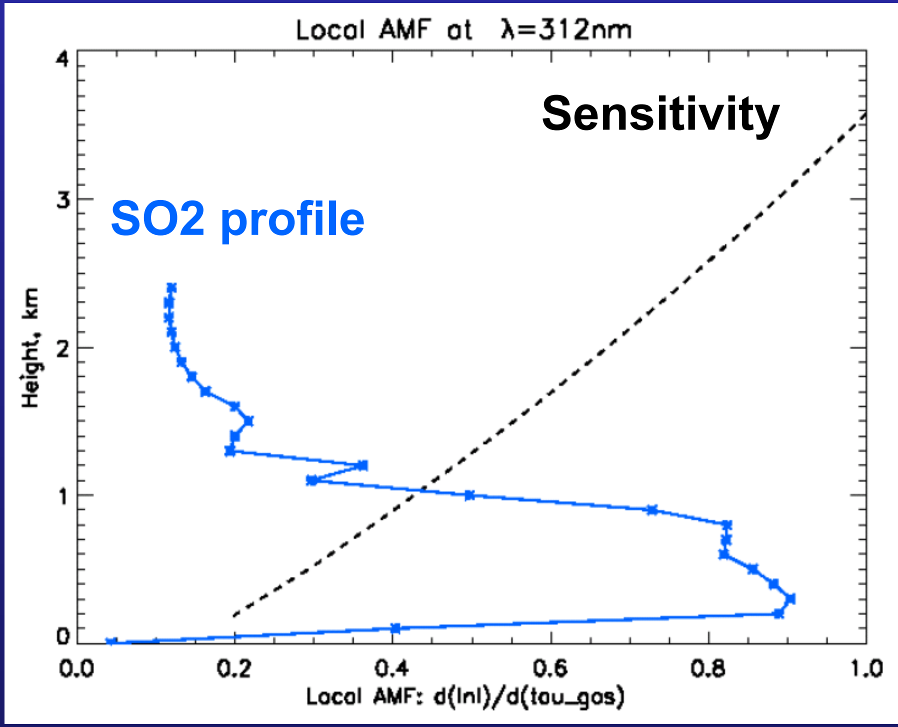
Promising Developments



Krotkov, Krueger, Carn et al.

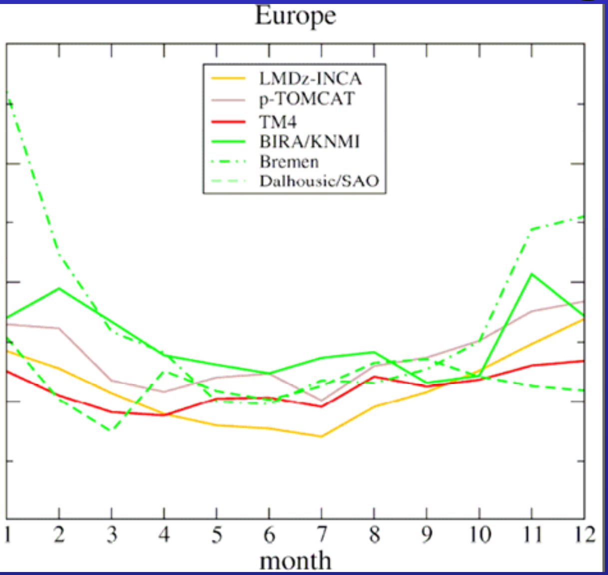
Remaining Challenges

- O_3 Interference
- Atmospheric Scattering
- Separation boundary layer and FT SO_2 (combine OMI-AIRS)



Van Roozendael et al.

True Validation Dataset for Air Quality Applications (tropospheric NO_2, HCHO, SO_2, Mixed Layer O_3) Flights during all four seasons



van Noije et al. [2006]

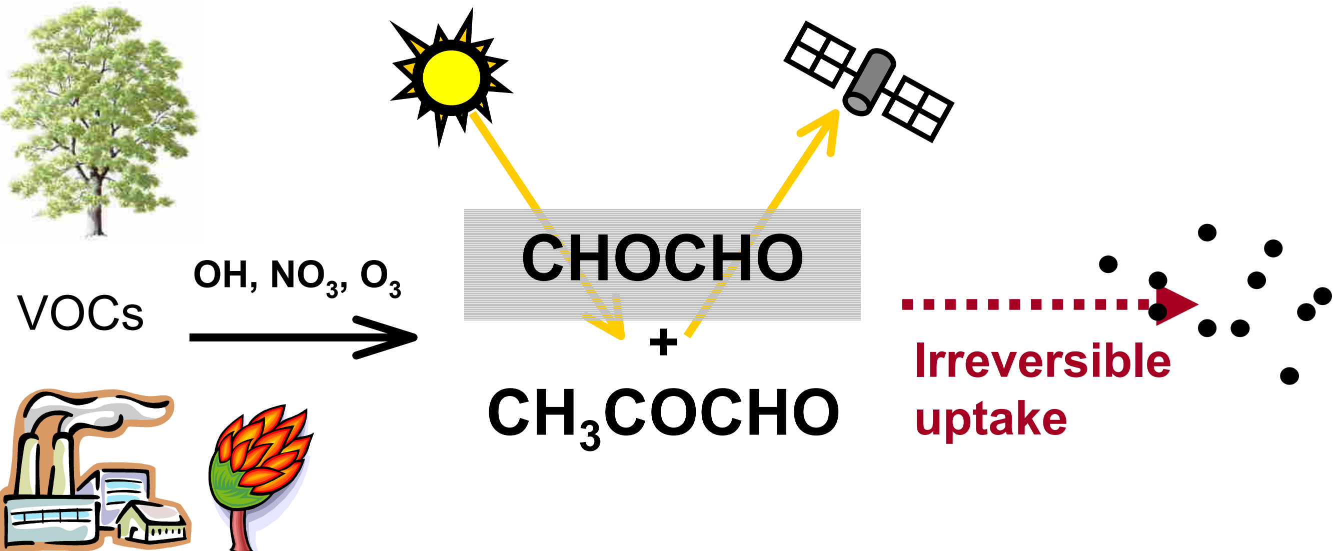
Spiral from tropopause to mixed layer

Coincident measurements in lower mixed layer over scale of satellite footprint

Profiles through lower mixed layer

Research-quality ground-level measurements

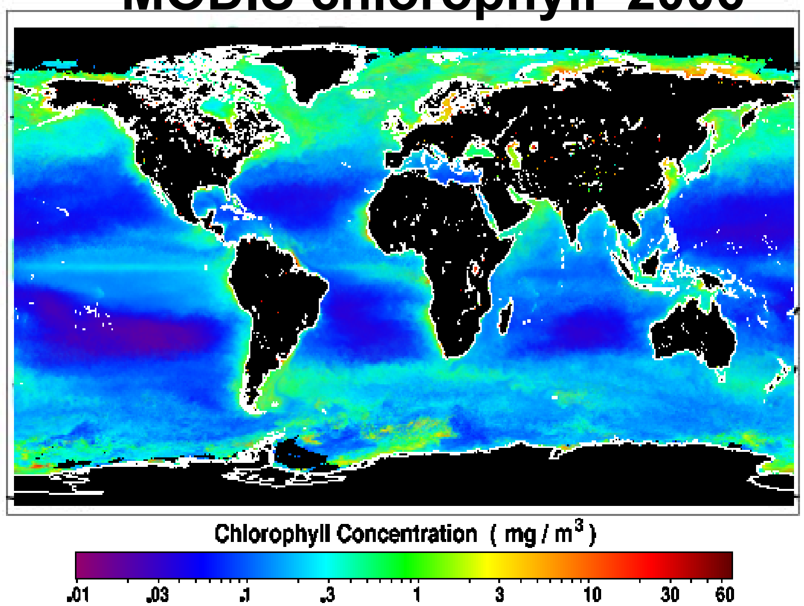
Interpretation of Glyoxal retrievals

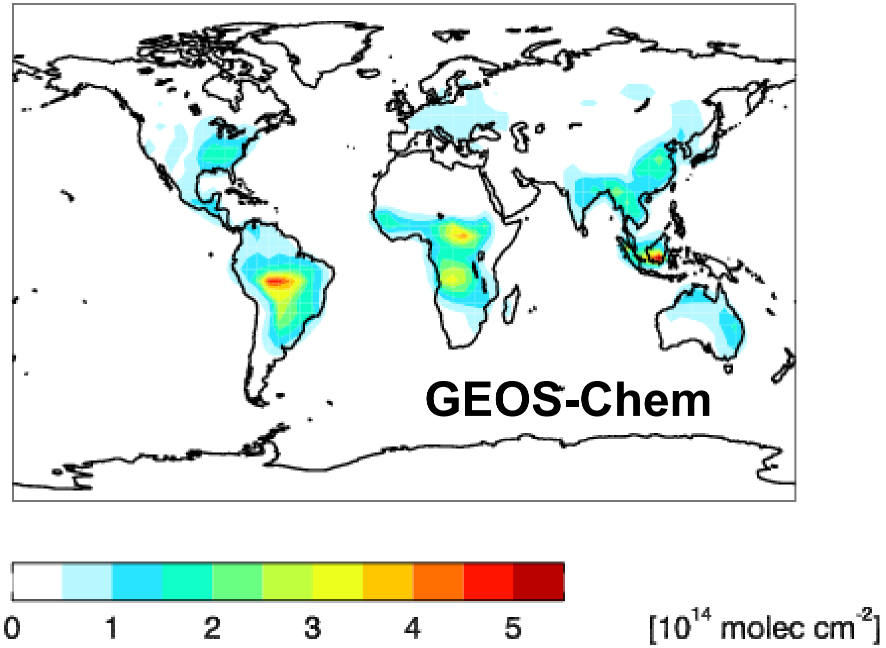


II SOA production via irreversible uptake of dicarbonyls

(never quantified)

MODIS chlorophyll 2006





Fu, Wittrock, Jacob et al. [2007]

Supporting the next generation

U.S.

- 4th most relevant Earth Science Question (Decadal Survey): How will economic development affect air pollution & transport across oceans & continents, & how are pollutants transformed during transport?
- NASA has 6 planned missions, all without air quality monitoring capability (Glory aimed at aerosols)
- NOAA has NPOESS with little air quality component

Europe

- 3x GOME-2 (EUMETSAT) until 2020 (but morning, low resolution)
- ESA has 6 approved Earth Explorer Missions, none of which address air quality (EarthCare aimed at clouds, aerosols)
- In 2008 ESA will select one from 6 proposed Earth Explorer Missions (one aimed at air quality (TRAQ)) – launch ~2015

Conclusion: No dedicated mission beyond study phase

Extra

Air Quality

The combination of requirements on revisit time, resolution and coverage, including frequent cloud-free sampling of the planetary boundary layer, is very stringent. The Air Quality requirements to meet user needs are not adequately addressed by the planned operational missions. Planned operational missions in LEO will contribute to, but by and large do not fulfil stringent Air Quality sampling requirements. Nominal mission lifetimes of the Envisat and EOS-Aura missions both end before 2010. Continuation of Air Quality user services based on these missions requires quick action to be taken. Moreover, planned operational missions have primarily meteorological and climate objectives. The Air Quality applications could benefit most from denser spatio-temporal sampling over Europe for forecasting and monitoring as well as globally for worldwide Air Quality monitoring and attribution of pollution episodes. The Air Quality user requirements include a suite of trace gases as well as aerosols.

CAPACITY concludes on the Air Quality theme:

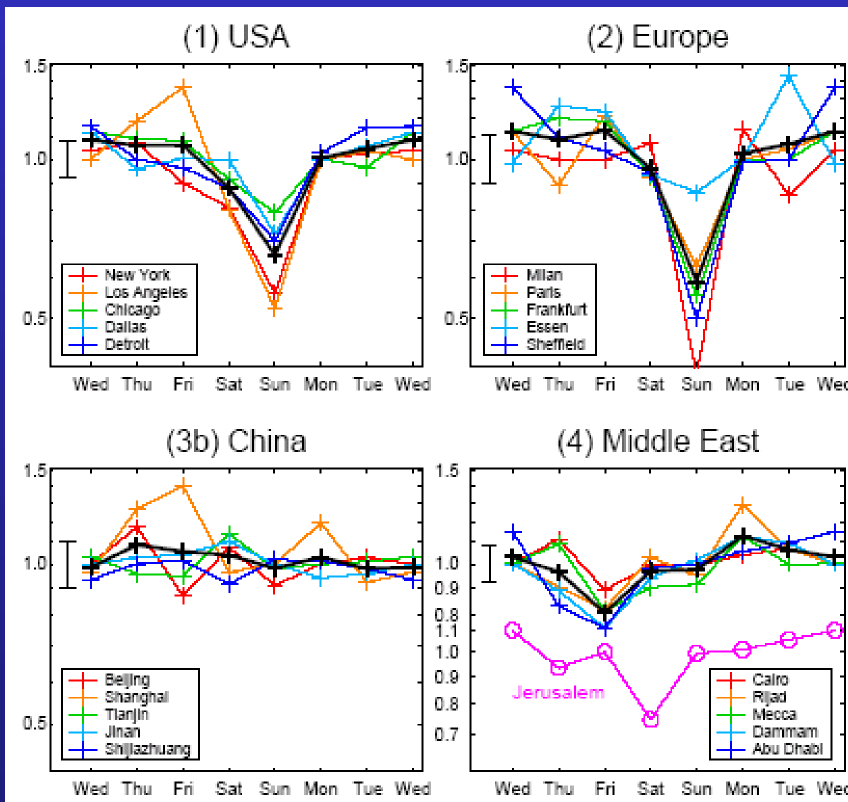
- that the monitoring for operational Air Quality applications needs to be optimised with respect to the density of spatio-temporal sampling of the planetary boundary layer,
- that small ground pixels are needed to maximize (cloud-free) sampling of the boundary layer,
- that it is important to cover diurnal variations for Air Quality
- that regional coverage with short revisit time is needed to optimally serve regional Air Quality forecasting and monitoring in Europe and that global coverage is required for the monitoring and assessment of Air Quality, the oxidising capacity, and the quantification of continental in/outflow.
- that *afternoon* observations would complement best the observation times of day of MetOp and NPOESS observations in the post-Envisat/post-EOS-Aura time period

For **implementation** of the Air Quality Mission CAPACITY recommends:

- to enhance observational capabilities in the 2010-2020 time period and afterwards for operational Air Quality applications with respect to the density of spatio-temporal sampling of the planetary boundary layer by a combination of space elements in Geostationary Orbit (GEO) and Low-Earth Orbit (LEO). The global (LEO) and regional (GEO) missions are of equal importance.
    - A LEO mission with a UV-VIS-NIR-SWIR nadir viewing spectrometer with ground pixel size significantly smaller than GOME-2 and OMPS and daily global coverage in a polar orbit with *afternoon* equator crossing time optimally chosen to complement on the times of day of MetOp and NPOESS observations in the post-Envisat/post-EOS-Aura time period and to maximize (cloud-free) sampling of the boundary layer. Global coverage is required for the monitoring and assessment of Air Quality, the oxidising capacity, and the quantification of continental in/outflow.
    - A combined GEO mission with a UV-VIS-NIR-SWIR spectrometer and TIR sounder with small ground pixel sizes to cover diurnal variations in O_3, CO, NO_2, SO_2, HCHO, HNO_3, PAN, N_2O_5, organic nitrates and aerosols, height-resolved tropospheric O_3 and CO, and to significantly improve upon the cloud-free sampling of the planetary boundary layer over Europe.
    - Taking into account maturity, cost and risk issues, it is recognised that a LEO mission could have a somewhat shorter lead time, even though it will only partially fulfil the requirements of European Air Quality users.
- to prepare for phase A studies in 2005/2006 for LEO and GEO missions targeting Air Quality (Protocol Monitoring, Forecasting and Assessment) based on the given definitions of the instrument / mission concepts and requirements and their subsequent evaluation, and taking into account the importance of cloud statistics on lower tropospheric observations.

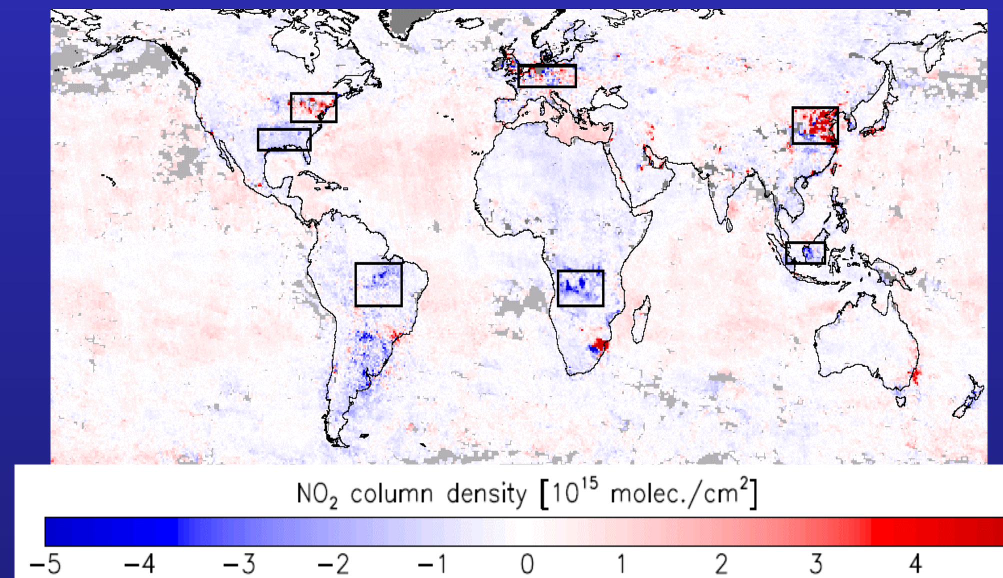
Day-to-day and Intra-day Variation in NO_2 Columns

Day of Week (GOME)



Beirle et al., 2003

SCIAMACHY (10 AM) – OMI (1:30 PM) for August 2006

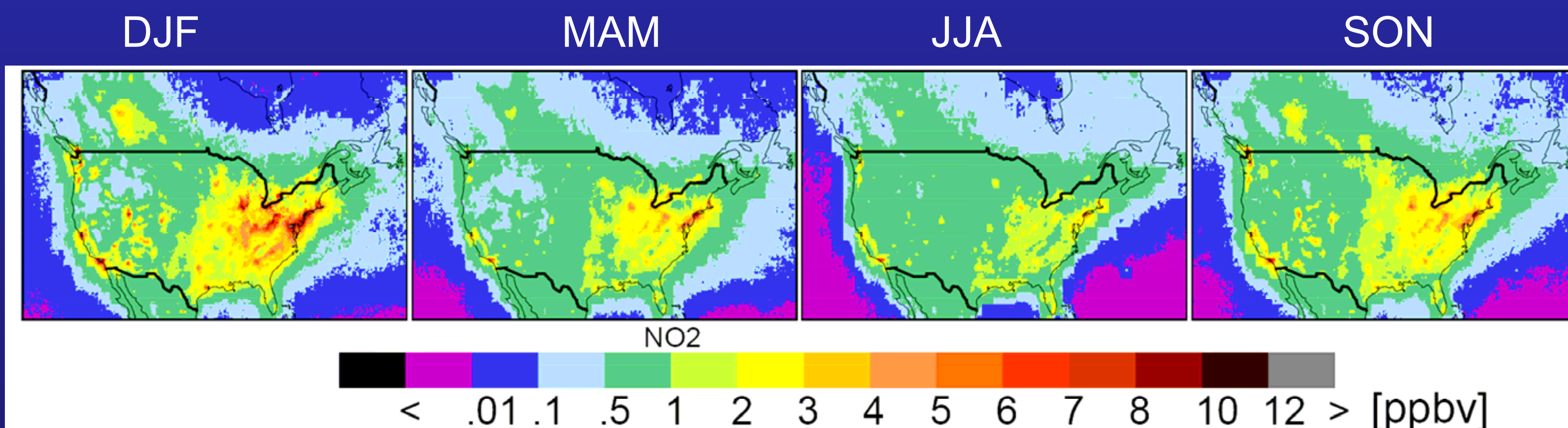


Diurnal variation driven by diurnal variation in emissions and photochemistry

Boersma et al., submitted

Surface NO_2 Inferred from Satellite

Figure showing correlation from GOME in Alps and/or Cohen's recent work



Lamsal et al., submitted

'State-of-science'

van Noije et al., ACP, 6, 2943-2979, 2006

	IUP Bremen	Dalhousie	KNMI/BIRA
$N_{s,st}$	**Ref. sector scaled to SLIMCAT strat.**	**Ref. Sector**	**Data-assimilation in TM4**
Cloud fraction	**FRESCO <0.2 cloud fraction; only cloud selection, no further correction**	**GOMECAT**	**FRESCO**
Cloud pressure	**Not used**	**GOMECAT**	**FRESCO**
Albedo	**GOME**	**GOME**	**TOMS/GOME**
Profile shape	**MOZART-2 run for 1997, monthly averages on 2.8 x 2.8 °**	**GEOS-Chem (2°x2.5°)**	**TM4 (3°x2°)**
Temperature correction	**No**	**Based on U.S. std. atmosphere**	**Based on ECMWF T-profiles**
Aerosols	**Based on LOWTRAN**	**Based on GEOS-Chem**	**No**

Error top-10

1. Cloud fraction errors	~30%
2. Surface albedo	~15% + resolution effect?
3. Vertical profile	~10% + resolution effect?
4. Aerosols	~10%? More research needed
5. Cloud pressure	~5%
6. Surface pressure	depends on orography

Is there a recipe for reducing all these errors?

1. Better estimates of forward model parameters

A good example: surface pressures (Schaub et al.)

What should be done:

- a validation/improvement of surface albedo databases
- a validation/improvement of cloud retrievals
- investigate effects aerosols on (cloud) retrievals
- validation vertical profiles
- higher spatial resolution (sfc. albedo, pressure, profile)

Is there a recipe for reducing all these errors?

2. How do we know if better forward model parameters improve retrievals?

We need an extensive, unambiguous and well-accessible validation database

Testbed for retrieval improvements:

- in situ aircraft NO_2 (Heland, ICARTT, INTEX)
- surface columns (SAOZ, Brewer, (MAX)DOAS)
- in situ profiles (Schaub/Brunner)
- surface NO_2 (regionally)

Is there a recipe for reducing all these errors?

3. Towards a common algorithm/reduced errors?

Difficult!

- Without testbed, verification of improvements is hard
- Improvements for one algorithm may deteriorate other algorithms, depending on retrieval assumptions
- Improved model parameters may work for some regions and some seasons, but not for others

Is there a recipe for reducing all these errors?

3. Towards a common algorithm/reduced errors?

Worth the try!

- Systematic differences can be reduced (emission estimates)
- Requires ‘scientific will’ – enormous task
    - Collection of validation set
    - Flexible algorithms digesting various model parameters
    - Intercomparison leading to recommendations
    - Fits purpose ACCENT/TROPOSAT